26(2)

気象庁欧文海洋報告

第26巻 第2号

THE OCEANOGRAPHICAL MAGAZINE

Vol. 26 No. 2

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Published by the Japan Meteorological Agency

March, 1975

The Oceanographical Magazine
Vol. 26, No. 2, pp. 49 to 56, March 1975

On the colorimetry of sea water containing suspended matter

Masao MATSUZAKI, Yoshisuke MAEDA and Shigeru MORIKAWA

Nagasaki Marine Observatory

(Received December 20, 1974)

Abstract: Experiments were made to establish a method of colorimetry free from the interference of suspended matter and also convenient to processing a large number of samples quickly on board the observation ship. Millipore filter is most desirable to remove the suspended matter but it takes much time to filter. The methods using other filters and the centrifugal method are not desirable because of the dissolution of nutrient salts from fiilter papers or from the suspended matter itself by vacuum filtration or centrifgal separation.

During the experiments the interference of color formation caused by suspended matter was found. The amount of interference (C) has a certain relation with turbidity (T) which is the blank extinction of turbid watar. True extinction (V) is given by the following formula:

$$V=V_o-T+C,$$

where V_o is the extinction of sample when the color forms. In field work, T and V_o can be obtained easily by reading the extinction of samples before and after the addition of the reagents, and C can be estimated by the correction curves obtained in the present experiment. This "calculation method" is very simple and the errors are allowable for all the practical purposes. It takes not so much time and no special apparatus is neccessary, except in case of extremely turbid water when millipore filter is recommended especially for nitrite-N determination.

1. Introduction

On the continental shelf of the East China Sea, highly turbid water has often been observed, and the color of water appears to be sometimes brown. Because of this turbidity the colorimetry of nutrients has been very difficult in this sea area. In order to establish a method free from this difficulty and also to process a large number of samples quickly on board the observation ship, experiments were made on the determinations of phosphate, nitrite and silicate.

2. Method

The first of effects of the existence of turbid substances on the colorimetry is shielding the light and increasing extinction.

In order to remove the suspended matter, some kinds of filtration, the centrifugal method and the calculation method were examined. During the experiments it was found that suspended matter interferes the color formation of nutrient and decreases the extinction value. On the other hand, in the process of the filtration with filter papers or separation by a centrifuge it is supposed that inorganic salts may dissolve in to the sample from the filter itself, or from suspended organic matter or living things. It also supposed that inorganic salts may be absorbed by the filter or instruments.

Hence the true extinction is considered as follows:

$$V = V_A + (A - D_F - D_S) - C, \tag{1}$$

where V_A: extinction after removing the suspended matter

V : true extinction

D_F: dissolution from filter

D_S: dissolution from suspended matter

A : absorption by the filter or instruments

C : interference to color formation by suspended matter.

The values of these terms were estimated from the experimental results.

To obtain the amount of absorption (A) and dissolution ($D = D_F + D_S$), standard solutions of known concentration of phosphate, silicate and nitrite were used and calculated as follows:

$$V_{SO} - V_{SA} = D - A, \tag{2}$$

where V_{SO}: extinction of standard solution, colored untreated

V_{SA}: extinction of standard solution, colored after treated.

When the dissolution is predominant, this value is plus.

To obtain the dissolution from filter or instruments (D_F) pure water was used and calculated as follows:

$$V_{WA} - V_{WO} = D_F, \tag{3}$$

where V_{WO}: extinction of pure water, colored untreated

V_{WA}: extinction of pure water, colored after treated.

When true extinction, absorption and dissolution are known, interference (C) is calculated from the formula (1) as:

$$C = V - (A - D_F - D_S) - V_A \tag{4}$$

or

$$C = V - (V_O - T), \tag{5}$$

where V_O: extinction of sample, colored untreated

T : extinction of sample, before colored, untreated (=turbidity).

The experiments were made on 25 April 1971 at 32°35′N, 123°00′E on board the observation ship Chofu Maru (266ton) drifting for about 12 hours. Turbid sea water was sampled with a Van Dorn sampling bottle from the depth of 40m, just above the sea bottom. To measure the extinction KODEN ANA-7D photoelectric colorimeter with recorder was used through the light path of 40mm.

Photometric determinations were carried out as follows: ascorbic acid method for phosphate, Bendschneider and Robinson method for nitrite and molybdenum yellow method for silicate.

3. Results

Two methods were examined to remove the effects of suspended matter. The first is physical method to remove the suspended matter before the addition of the reagent and the second is "calculation method" which removes the effects of suspended matter by a calculation using turbidity.

A. Physical methods

The ability of removing the suspended matter (R) is represented as:

$$R = \frac{T - T_A}{T} \times 100 \ (\%),$$

where T_A is extinction of sample after treated.

Results of examination are shown in Table 1. Millipore filter (AAWP) showed the satisfactory removal of turbid substances.

Table 1. Ability of removing the suspended matter from sea water sample.

Wavelength (mμ)	700	530	420
Nutrients	P_2O_5	NO_2	SiO_2
Filter paper No. 2	84%	80	76
No. 5c	98	86	93
Glass fiber filter	88	99	97
Millipore filter (AAWP)	100	100	100
Centrifuge (2000r/m, 5min.)	94	97	95

No absorption (A) was observed at all materials.

Dissolution (D) was calculated by Formulas (2) and (3). Results are shown in Table 2. Filter paper No. 2 (for qualitative analysis) recorded a considerable amount of dissolution. It was found by another experiment that a large amount of nutrients dissolutes from filter paper No. 2 itself. Dissolution by centrifugal method was considered as D_S caused by centrifugal force. D_S is also seen on the

case of Millipore filter (AAWP) under strong vacuum sucktion when the pores are choked. Another type of filter paper for quantitative analysis (No. 6) was examined but the result was about the same with No. 5c.

Table 2. Dissolution of nutrients caused by treatment.

Wavelength (mμ)	700	530	420
Nutrients	P_2O_5	NO_2	SiO_2
Filter paper No. 2	+	+	+
〃 No. 5c	−	−	−
Glass fiber filter	−	−	−
Millipore filter (AAWP)	−	−	−
Centrifuge (2000r/m, 5min.)	−	+	+

A symbol + means existence of dissolusion.

From the above experimental results, filtration through Millipore filter (AAWP) is considered to give the nearest value to the true extinction for each nutrient. Then regarding the value obtained through Millipore filter (AAWP) as true extinction, the values of interference (C) calculated from Formula (4) and represented by reading of colorimeter are shown in Table 3.

Table 3. Interference to color formation by the suspended matter.

Wavelength (mμ)	700	530	420
Nutrients	P_2O_5	NO_2	SiO_2
Filter paper No. 2	2.7	0.2	1.0
〃 No. 5c	2.0	0.2	1.3
Glass fiber filter	2.0	0.0	0.5
Centrifuge (2000r/m, 5min.)	2.3	*	0.5

* Impossible to calculate because of high dissolution.

The results are nearly in proportion to the ability of removing the suspended matter. This proves that suspended matter is mainly the cause of the interference to color formation of nutrients.

B. "Calculation Method"

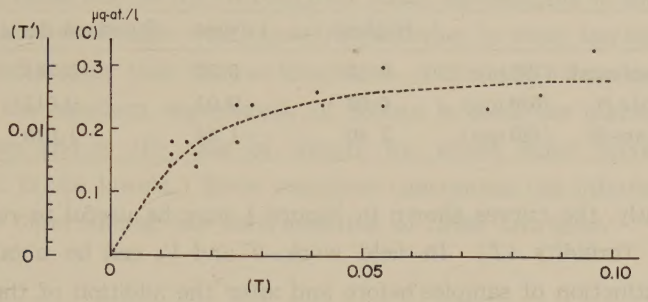
If the interference (C) is in proportion to the amount of suspended matter, i.e., turbidity (T), and is not associated with the concentration of nutrients, it can be estimated by measurement of T.

True extinction (V) is expressed as follows from Formula (5):

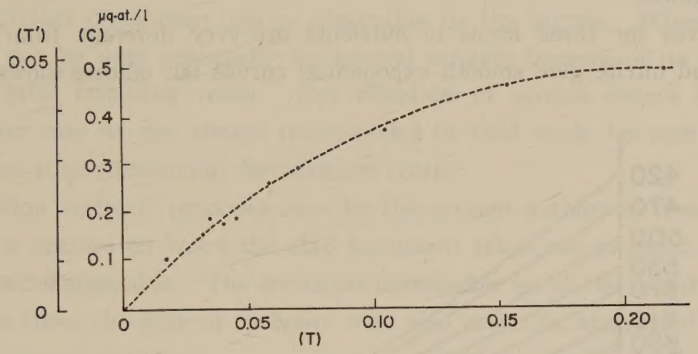
$$V = V_0 - T + C, \qquad (6)$$

and if $C<V$ or $V_0-T>0$, V can be calculated.

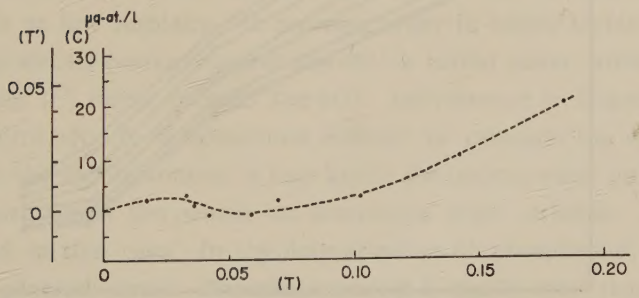
The interference (C) was investigated with different turbidity and concentration of three kinds of nutrients. In order to obtain true extinction (V), filtlation with Millipore filter was used. The results are shown in Figures 1-(a), -(b) and -(c).



(a) Phosphate-P



(b) Nitrite-N



(c) Silicate-Si

Fig. 1. Relationship between turbidity (T: represented by extinction value) and the interference (T': extinction value, C: concentration of nutrients). (a): Phosphate-P, (b): Nitrite-N, (c): Silicate-Si.

Certain relations were observed between C and T in every nutrient. The relations were not associated with the concentration of nutrients and the fluctuation of "C" from the mean value is relatively small as shown in Table 4.

Table 4. Fluctuation of "C" from the mean value(μg-atoms/l).

	Highest	Lowest	Standard deviation
Phosphate-P (700 mμ)	0.22	−0.22	0.145
Nitrite-N (530 mμ)	0.02	−0.02	0.012
Silicate-Si (420 mμ)	2.40	−1.44	1.010

Consequently, the curves shown in Figure 1 may be useful to read the correction (C) from turbidity (T). In field work, T and V_0 can be obtained easily by reading the extinction of samples before and after the addition of the reagents and C by these curves, then calculate the true extinction by Formula (6) and determine the concentration.

The curves for three kinds of nutrients are very different from each other. Phosphate and nitrite give smooth exponential curves but silicate shows a complex

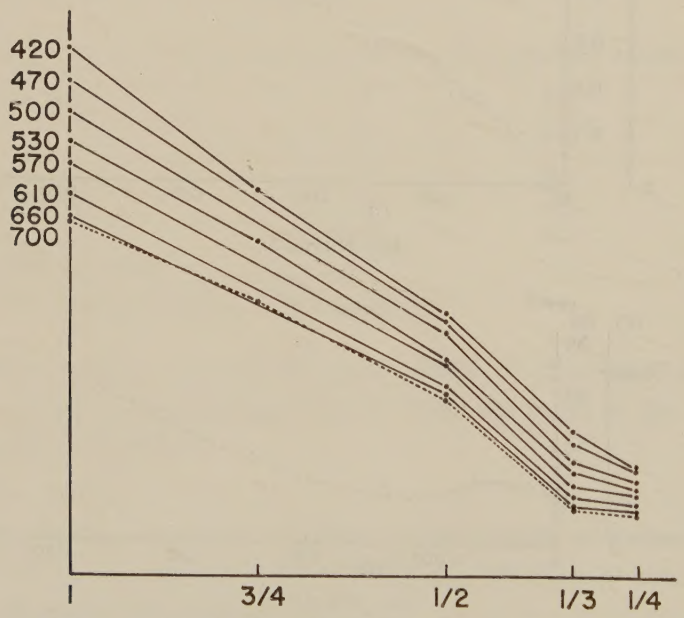


Fig. 2. Difference of extinction of turbidity with respect to wavelength used for measurement. Abscissa is turbidity expressed by the rate of dilution. Ordinate is extinction. Numbers are wavelength (mμ).

curve which has two minima. These differences are considered to be caused by the difference of color of three nutrients developed by reagents and may have a relation to the color of suspended matter. Color formation of phosphate is in bluish purple, nitrite in pink and silicate in yellow which resembles the color of turbid water.

Extinction value due to the turbidity for some wavelengths is shown in Fig. 2. It shows that short-wave light which penetrates further in water has higher sensitivity for suspended matter than that of long wave. But in the measurement of nitrite-N for which the medium wavelength of 530mμ is used, the highest influence of turbidity is seen and in the case of silicate for which short wavelength of 420 mμ is used, it is the lowest. Some reactions concerning the inferference to color formation may differ among the determination of these nutrients.

4. Conclusion

Millipore filter (AAWP) is most desirable to remove the suspended matter. It shows no nutrient dissolution into or absorption by the sample. When the turbidity is low, it can be used repeatedly for several samples because of its very narrow width and little retaining water. But filtration of sample waters through the Millipore filter may be not always recommeded in field work, because the method is tedious and time-consuming, furthermore costly.

"Calculation method" proposed here by the present authors is considered to be convenient to operate on board the ship because it takes not so much time and requires no special apparatus. The errors are permissible for all the practical purposes. At the same time, the data of turbidity may also useful for analysis of hydrographic condition.

In the determination of silicate-Si, the correction due to turbidity (C) is very small especially at low turbidity. It becames larger in highly turbid water. In the East China Sea silicate content exceeds 20μ-at/l in turbid water, while the correction due to turbidity (C) rarely exceeds 3μg-at/l. Interference is largest in the determination of nitrite-N. It is sometimes difficult to calculate the concentration of nitrite because the nitrite content is very low in the bottom water on the continental shelf in the East China Sea which has sometimes high turbidity. Millipore filter should be used in this case. In the determination of phosphate-P, correction due to turbidity is generally small. Phosphate content is usually more than 0.5μg-atoms/l in turbid water. Millipore filter is recommended only for extremely high turbid water.

Old data of these nutrients concentrations obtained for the turbid waters of the

East China Sea may be unreliable.

Acknowledgements

The authors express their hearty thanks to Mr. Tsutomu AKIYAMA of Japan Meteorological Agency for his critical reading of this report and suggestions. Great thanks are due to Mr. Fukutarō SHINJI, the director of the Oceanographical Section of the Nagasaki Marine Observatory, and to the members of that section for their assistance and encouragement in executing these experiments.

Thanks are also due to Captain Mitsuo AMEMIYA and the officers and crew of R/V Chōfū Maru for their help for this study.

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濁りのある海域における比色分析について

松崎正夫・前田吉祐・森川　滋

（長崎海洋気象台）

海水の比色分析をおこなう際，水の濁りが大きな障害となっている。この濁りの影響を除去しつつ，船上で多量の試水を速やかに処理できる方法を確立するため，1971年4月，東シナ海の濁りの多い海域で三種の栄養塩について実験をおこなった。

濁りはミリポアフィルター（AAWP）でほぼ完全に除去されたが，処理に長時間を要し，また装置やフィルター自身高価なことが欠点であった。他の濾紙や遠心分離法では濁りは十分に除去できず，また塩類の溶出が観測されたものもあった。

濁りの存在は試薬による栄養塩の発色を妨害することが発見された。この妨害の値（C）は濁りの度合と一定の関係があった。そこで真の吸光値（V）は，

$$V=V_0-T+C$$

と計算される。ここでTは発色前に測定した試水の吸光値（濁度），V_0は発色後の試水吸光値である。発色試薬を加える前と後にそれぞれ吸光値を測定し，本報に示した$T-C$グラフによってCを読み取れば，上式によってVを計算することができる。この「計算法」は最も簡単であり，誤差は実用上許される範囲であった。しかし亜硝酸塩については，濁りの非常に多い試水中ではミリポアフィルターの併用が望ましいと考えられた。

The Oceanographical Magazine
Vol. 26, No. 2, pp. 57 to 62, March 1975

On the distribution of chaetognaths in the East China Sea

Masao MATSUZAKI

Nagasaki Marine Observatory

(Received December 20, 1974)

Abstract: The relationships between chaetognaths and water masses are studied on the basis of the data obtained on the cruises of the R/V Chōfū Maru of the Nagasaki Marine Observatory in the East China Sea during from 1969 to 1972.

From 149 plankton samples collected in four years, 4 genera and 20 species of chaetognaths are identified by the author. These chaetognaths are divided into three groups and two subgroups by the properties of behavior of them in relation to the hydrographic conditions. Group I consists of the coastal water species such as *Sagitta crassa*, *S. crassa* forma *naikaiensis* and *S. nagae*, group III of the Kuroshio water species, as *S. lyra*, *S. haxaptera* and *Krohnitta subtilis*, and group II of the mixed water species, as *S. minima*, *S. reglaris*, *S. pacifica*, *S. neglecta*, *S. ferox* and *Krohnitta pacifica*. Group II is divided into two subgroups; the one is composed of the species such as *S. enflata*, *S. pulchra* and *S. bedoti* which are distributed in the waters influenced by the coastal water, and the other of *S. robsta*, *S. pseudoserratodentata* and *Pterosagitta draco* which are in the waters influenced by the Kuroshio water.

Chaetognaths of each group and subgroup are considered to be useful as the indicators of water masses in the East China Sea.

1. Introduction

FURUHASHI (1958) reported the distributions of 17 species of chaetognaths in the East China Sea for the winter and summer of 1956 and pointed out that some species of chaetognaths can be indicators of the water masses in the East China Sea.

Until 1961, distributions of chaetognaths in the East China Sea were studied continuously by the many workers of the Nagasaki Marine Observatory. Having been engaged in this work since 1965, the present author recorded 4 genera and 20 species of chaetognaths (Table 1). Some of them are being used for indicators of water masses.

The present studies are intended to support the determination of the indicator species of water masses in the East China Sea on the basis of the data obtained in 4 years from 1969 to 1972.

Table 1. List of species recorded in the East China Sea during the period 1965 to 1974. Symbol ++ shows very common, + shows common, − shows rare species.

+	*Sagitta bedoti* BÉRANECK	−	*S. neglecta* AIDA
−	*S. bipunctata* QUOY et GAIMARD	++	*S. pacifica* TOKIOKA
−	*S. crassa* TOKIOKA	+	*S. pseudoserratodentata* TOKIOKA
+	*S. crassa* forma *naikaiensis* TOKIOKA	−	*S. purchra* DONCASTER
−	*S. decipiens* FOWLER	++	*S. regularis* AIDA
++	*S. enflata* GRASSI	+	*S. robusta* DONCASTER
+	*S. ferox* DONCASTER	+	*Pterosagitta draco* (KROHN)
+	*S. hexaptera* D'ORBIGNY	+	*Krohnitta pacifica* (AIDA)
+	*S. lyra* KROHN	+	*K. subtilis* (GRASSI)
++	*S. minima* GRASSI	−	*Eukrohnia hamata* (MÖBIUS)
++	*S. nagae* ALVARIÑO		

2. Method

One hundred and forty-nine samples of zooplankton were collected by vertical hauls of a Norpac net from 150m depth to the surface in the East China Sea both

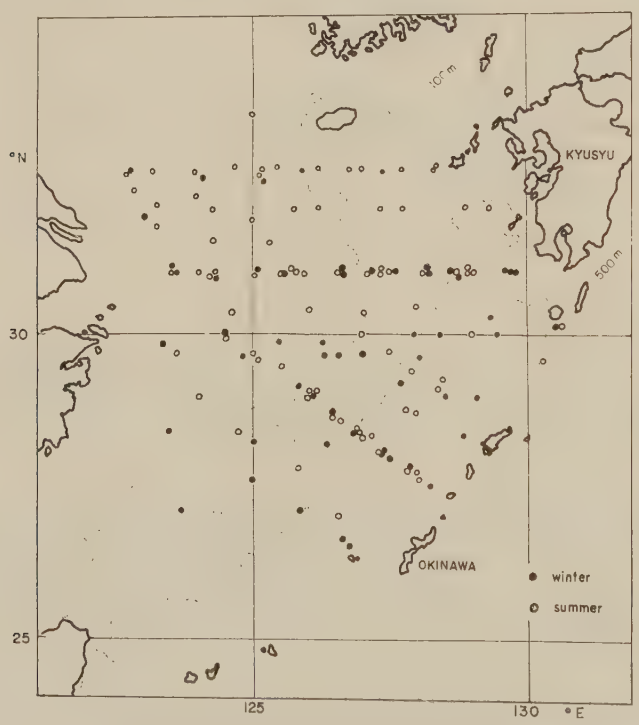

Fig. 1. Station locations where plankton samples were collected in 1969–1972. ●: winter, ○: summer

in winter and summer during from 1969 to 1972. When the water depth was less than 150m, a Norpac net was towed vertically from the bottom to the sea surface. The Norpac net used in samplings measures 45cm in mouth diameter and 180cm in length along the side; it is made of bolting cloth, GG54, i.e., 52.5 meshes a linear inch. The approximate sampling positions are shown in Figure 1.

Water temperature and salinity at the depth of 50m at the stations where the plankton samples were collected, are averaged in summer and winter, respectively. These average values are calculated as follows:

$$\bar{T} = \frac{t_1 \times n_1 + t_2 \times n_2 + \cdots\cdots + t_n \times n_n}{n_1 + n_2 + \cdots\cdots + n_n}$$

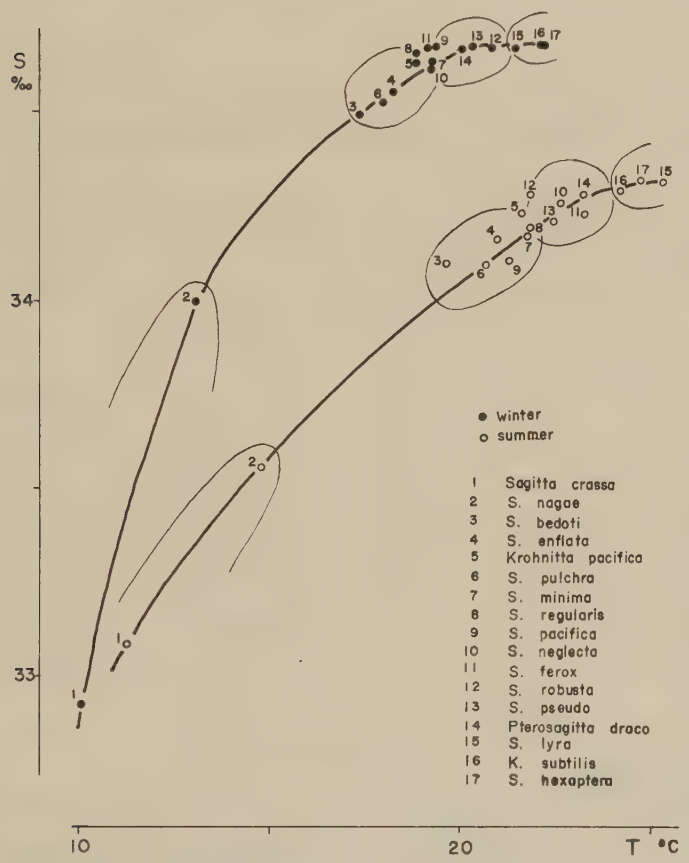

Fig. 2. Relationship between chaetognaths and the average values of temperature and salinity at 50m depth in the East China Sea in 1969–1972.

$$\bar{S}=\frac{s_1\times n_1+s_2\times n_2+\cdots\cdots+s_n\times n_n}{n_1+n_2+\cdots\cdots+n_n}$$

where, T: the average water temperature

$t_1, \cdots, t_n$: water temperatures at the depth of 50m at the sampling positions of plankton

S: average salinity

$s_1, \cdots, s_n$: salinity at the same depth and position as in water temperatures

$n_1, \cdots, n_n$: individual numbers of a species of chaetognaths per ten cubic meters of water.

These calculations are made on each species of chaetognaths and the results are shown in Table 2 and Figure 2.

3. Results

From the relationships between chaetognaths and water temperature and salinity, chaetognaths seemed to be divided into three groups which correspond to

Table 2. Average water temperature and salinity at 50m depth at the stations where chaetognaths samples were collected in the East China Sea in 1969–1972.

	Winter		Summer		
	T°C	S‰	T°C	S‰	
1. *Sagitta crassa*	10.0	32.93	11.2	33.09	(I) The coastal water species
2. *S. nagae*	13.1	34.00	14.8	33.56	
3. *S. bedoti*	17.4	34.50	19.7	34.10	
4. *S. enflata*	18.3	34.56	21.0	34.17	
5. *Krohnitta pacifica*	18.9	34.64	21.7	34.24	
6. *S. pulchra*	18.0	34.53	20.7	34.10	
7. *S. minima*	19.3	34.64	21.8	34.18	
8. *S. regularis*	18.9	34.66	21.9	34.20	(II) The mixed water species
9. *S. pacifica*	19.4	34.68	21.3	34.11	
10. *S. neglecta*	19.3	34.62	22.7	34.27	
11. *S. ferox*	19.2	34.68	23.3	34.24	
12. *S. robusta*	20.9	34.68	21.9	34.29	
13. *S. pseudoserratodentata*	20.4	34.68	22.5	34.22	
14. *Pterosagitta draco*	20.1	34.67	23.3	34.29	
15. *S. lyra*	21.5	34.68	25.4	34.32	(III) The Kuroshio water species
16. *K. subtilis*	22.2	34.69	24.3	34.30	
17. *S. hexaptera*	22.2	34.69	24.8	34.33	

* contains *S. crassa* f. *naikaiensis*.

three main water masses in the East China Sea.

Group I including *Sagitta crassa*, *S. crassa* forma *naikaiensis* and *S. nagae* is composed of the indicator species of the coastal water mass, water temperature of which is below 15°C and salinity is below 34.0‰ both in winter and summer. Group III including *S. lyra*, *S. hexaptera* and *Krohnitta subtilis* is composed of the indicator species of the Kuroshio water mass, water temperature of which is higher than 21°C and salinity is higher than 34.65‰ in winter, and water temperature is higher than 24°C and salinity is higher than 34.3‰ in summer. Group II comprising the other species of chaetognaths is composed of the indicator species of the mixed water of the Kuroshio and the coastal waters. The mixed waters spread widely on the continental shelf, so very common species such as *S. enflata*, *S. pacifica*, *S. regularis* and *S. minima* are included in Group II. Those species appear in the wide ranges of temperature and salinity. This group is divided into two subgroups. The one inlcuding *S. bedoti*, *S. enflata* and *S. pulchra* is commonly distributed in the mixed water area influenced by the coastal waters and the other including *S. robusta*, *S. pseudoserratodentata* and *Pterosagitta draco* is in the waters influenced by the Kuroshio water.

Eukrohnia hamata was collected only from the deep water of the Kuroshio.

Chaetognaths of each group and subgroup are considered to be useful as the indicator of each water mass in the East China Sea.

Acknowledgements

The author expresses his hearty thanks to Dr. Yutaka KAWARADA of the Japan Meteorological Agency for his critical reading of this report and suggestions. Great thanks are due to Mr. Fukutarō SHINJI, the director of the Oceanographical Section of the Nagasaki Marine Observatory, and to the members of that section for their encouragement.

Thanks are also due to the officers and crew of the R/V Chōfū Maru for their effort in collecting samples.

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The Oceanographical Magazine, Vol. 26. No. 2 (1975)

東シナ海におけるヤムシ類の分布について

松　崎　正　夫

(長崎海洋気象台)

ヤムシ類は海況の指標として水塊分析にとり入れられており，当海域では4属20種が知られている。今回はそれらの海況指標性を確かめるために水温と塩分との関係を調査した。1969年から1972年にかけての夏季と冬季に東シナ海で採集されたヤムシ類17種について，その採集時の水温と塩分を10 m^3 当りの個体数で加重し平均した。この平均水温，塩分によって各種類は三つの大群と二つの小群に分けられ，それは東シナ海の水塊の性質とよく対応している。

The Oceanographical Magazine
Vol. 26, No. 2 pp, 63 to 72, March, 1975

On the seasonal changes of some chaetognaths in the East China Sea

Masao MATSUZAKI

Nagasaki Marine Observatory

(Received December 20, 1974)

Abstract: Seasonal changes of some chaetognaths are studied on the basis of the data obtained at the ten fixed stations in the East China Sea during the period from April 1972 to October 1973.

It is supposed from the fact of the richness in population as well as of the presence of adult forms in the period from January to July that *Sagitta nagae* is reproduced during the period from winter to summer in the area investigated. On the other hand, *S. enflata* seems to be reproduced during the period from summer to winter, because of its absence in April and of the richness in population in the period from July to January.

Although small in quantity, *S. hexaptera* and *S. lyra* occur throughout the seasons observed. Therefore, the reproductive periods of these species are obscure in the area investigated.

1. Introduction

The oceanographic observations including the collection of plankton samples at the fixed stations in the Section PN which crosses three main water masses, the Kuroshio, the coastal and the mixed waters in the East China Sea were carried out in every three months during the period from April 1972 to October 1973. Using the data obtained in these series of observations, seasonal changes of some chaetognaths in relation to the hydrographic conditions are studied.

2. Method

Chaetognaths samples were collected by vertical hauls of a Norpac net from 150m depth or from the bottom at the stations shallower than 150m in depth to the surface in the Section PN and station C-6 during the period from 1972 to 1973 (Fig. 1), and numbers of individual chaetognaths were counted for each species under microscope and expressed in the numbers of individuals per ten cubic meters of water. Body length and numbers of mature and immature individuals of two

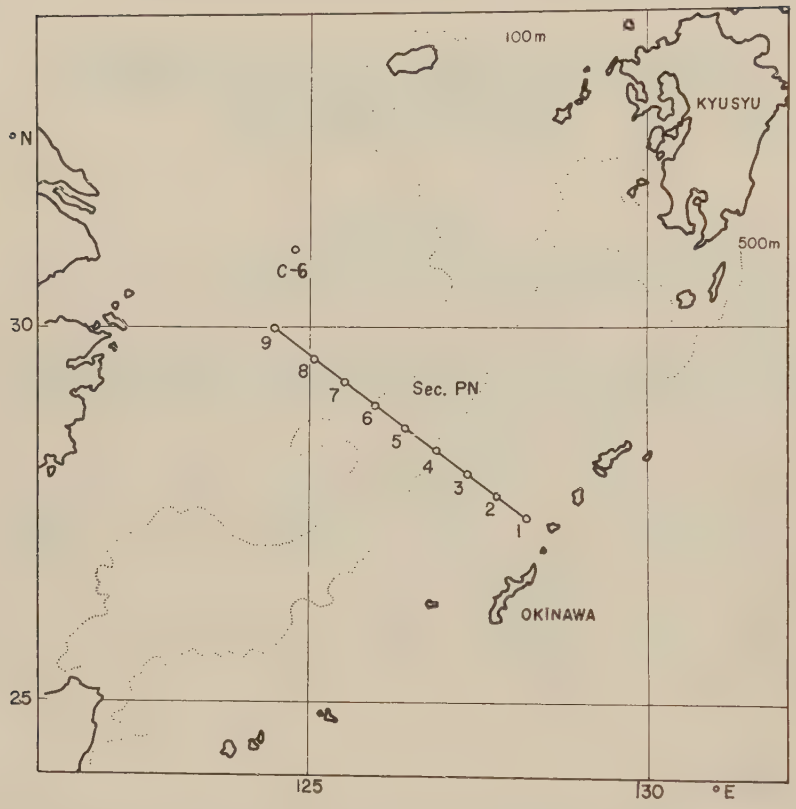

Fig. 1. Location of the stations where the plankton samples were collected.

important species, *Sagitta nagae* and *S. enflata*, were also measured and counted. *S. enflata* is the dominant species of chaetognaths in the East China Sea and the indicator species of the mixed water of the Kuroshio and the coastal waters. *S. nagae* is the common species in the coastal waters and the important indicator species of the water mass.

3. Results

The seasonal changes of the total chaetognaths are shown in Fig. 2 and those of the individual numbers of *S. nagae, S. enflata* and *S. hexaptera* including *S. lyra* are shown in Figs. 3, 4 and 5, respectively. The total populations of chaetognaths are large in July, being more than 200 individuals per ten cubic meters of water, at the stations from PN-4 to PN-9 on the continental shelf, and are very small in

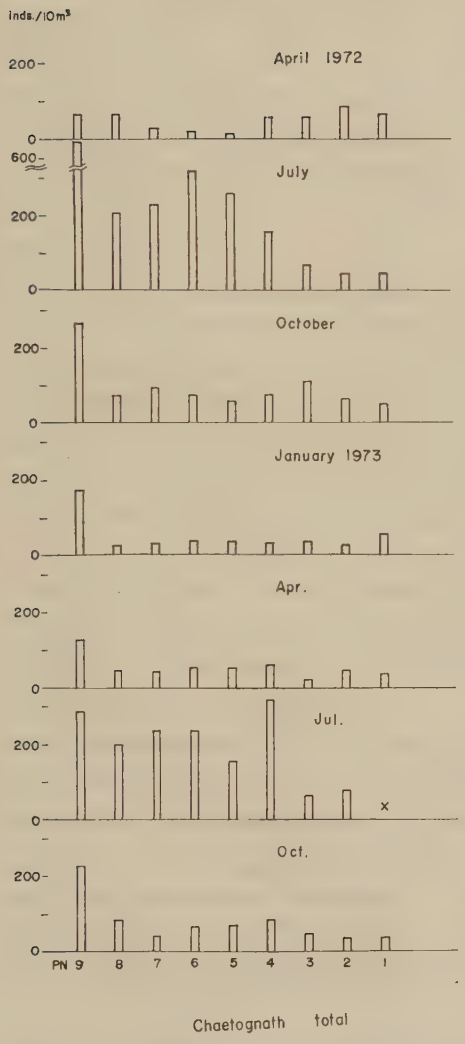

Fig. 2. Seasonal changes of the total numbers of chaetognaths per ten cubic meters of water at the stations in the Section PN. A mark × indicates the missing value.

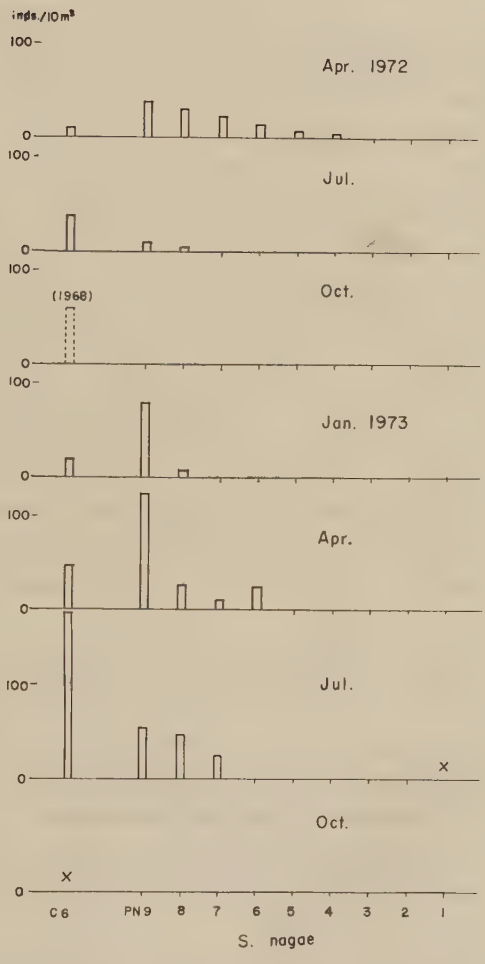

Fig. 3. Seasonal changes of the individual numbers of *S. nagae* per ten cubic meters of water at the stations in the Section PN. A mark × indicates the missing value.

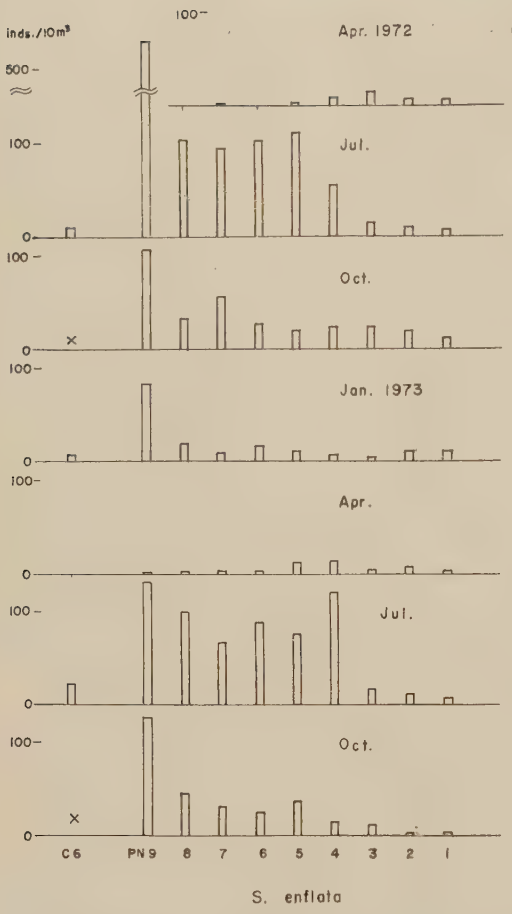

Fig. 4. Seasonal changes of the individual numbers of *S. enflata* per ten cubic meters of water at the stations in the Section PN. A mark × indicates the missing value.

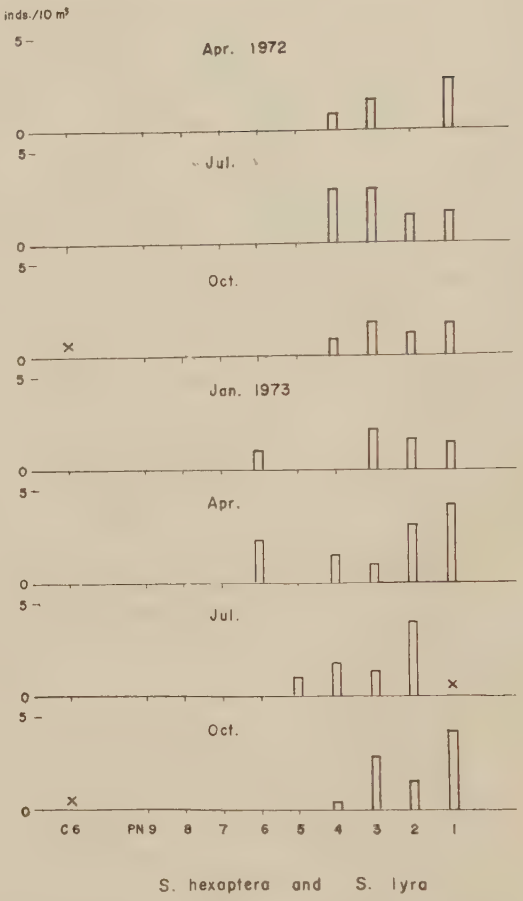

Fig. 5. Seasonal changes of the individual numbers of *S. hexaptera* and *S. lyra* per ten cubic meters of water at the stations in the Section PN. A mark × indicates the missing value.

the period from October to April except station PN-9. The populations in each month in 1972 were nearly the same order of magnitude in the corresponding month in 1973, except in July 1972 when the large number were found at station PN-9. The water at station PN-9, the westernmost station of the observation line, may be much influenced by the neritic nature of water, and then such a large population may occur in relation to the hydrographic conditions.

S. nagae increases in number during the period from January to July at the inner part of the continental shelf and is entirely absent in October. The populations of *S. nagae* in July 1973 were larger than in the corresponding month in 1972, while they were fairly large in April showing no difference between both years. Therefore, the most dense population of *S. nagae* appears in April in the area investigated. At station C-6 located at 31°00′N, 124°45′E, large amount of *S. nagae* was seen in July 1973. All the specimens identified here are juvenile forms. The hydrographic conditions at the station may be much influenced by the neritic nature of water.

On the other hand, *S. enflata* increases in number during the period from July to January and decreases in number in April. *S. enflata* is the most predominant species among chaetognaths group composed of 4 genera and 20 species mentioned in the previous paper (MATSUZAKI, 1975). Therefore, the seasonal variations of the total populations of chaetognaths mentioned above quite resemble to those of the individual numbers of *S. enflata*. The maximum population of *S. enflata* occurs in July, showing no difference in number between 1972 and 1973.

S. hexaptera and *S. lyra*, the representative indicator species of the Kuroshio water do not show notable change in number throughout the seasons observed. Though small in quantity, the populations of both species are seen in every month in nearly the same quantity, so the reproductive periods of these species are obscure in the area investigated.

Seasonal changes of the frequency distributions of the body length and the adult and juvenile forms of *S. nagae* and *S. enflata* are shown in Figs. 6 and 7, respectively. The adult forms of *S. nagae*, appeared in the period from April to July 1973. In other periods, juvenile forms alone occurred. From the seasonal variations of the populations of *S. nagae* and those of the adult forms of the species, the reproductive period of *S. nagae* seems to be during the period from winter to summer in the area investigated. On the other hand, the adult forms of *S. enflata* occur in the period from July to January and are entirely absent in April. It is supposed that the reproductive period of *S. enflata* may be in the period from July to January in the East China Sea.

It is well known that the waters on the continental shelf in the East China Sea are mixed by the vertical circulation from the surface to the bottom in winter. The mixing of water takes place in late October and continues until late April. In this period, the water masses here are homogeneous from the surface to the bottom. From late April the stratification of water takes place, and warm and

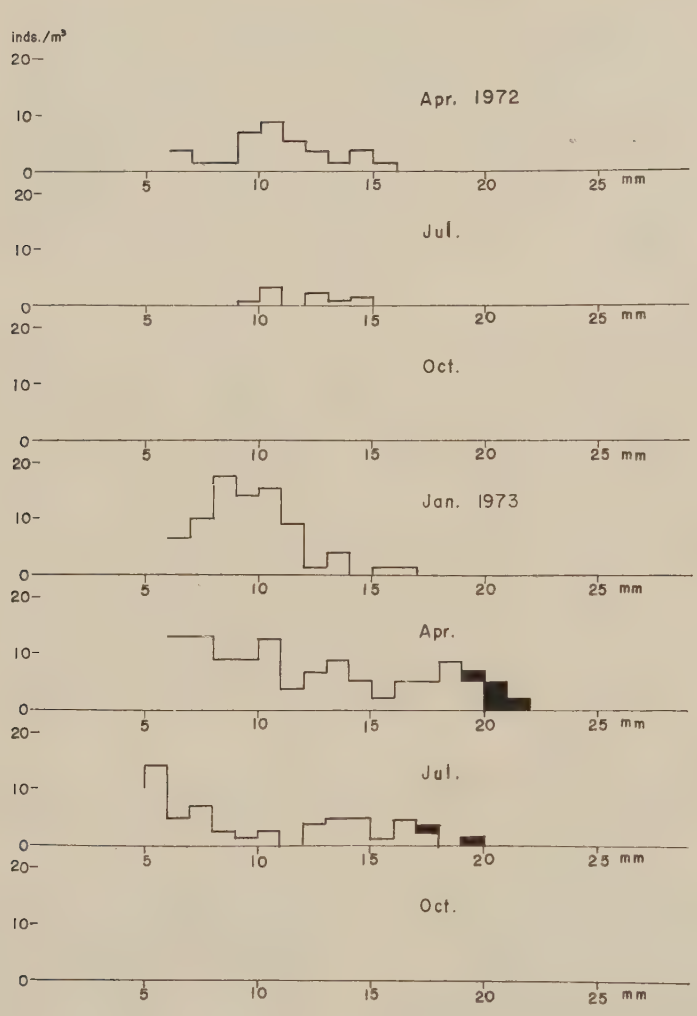

Fig. 6. Seasonal changes of the frequency distributions of the body length of *S. nagae* at the stations in the Section PN. Black columns show the mature forms.

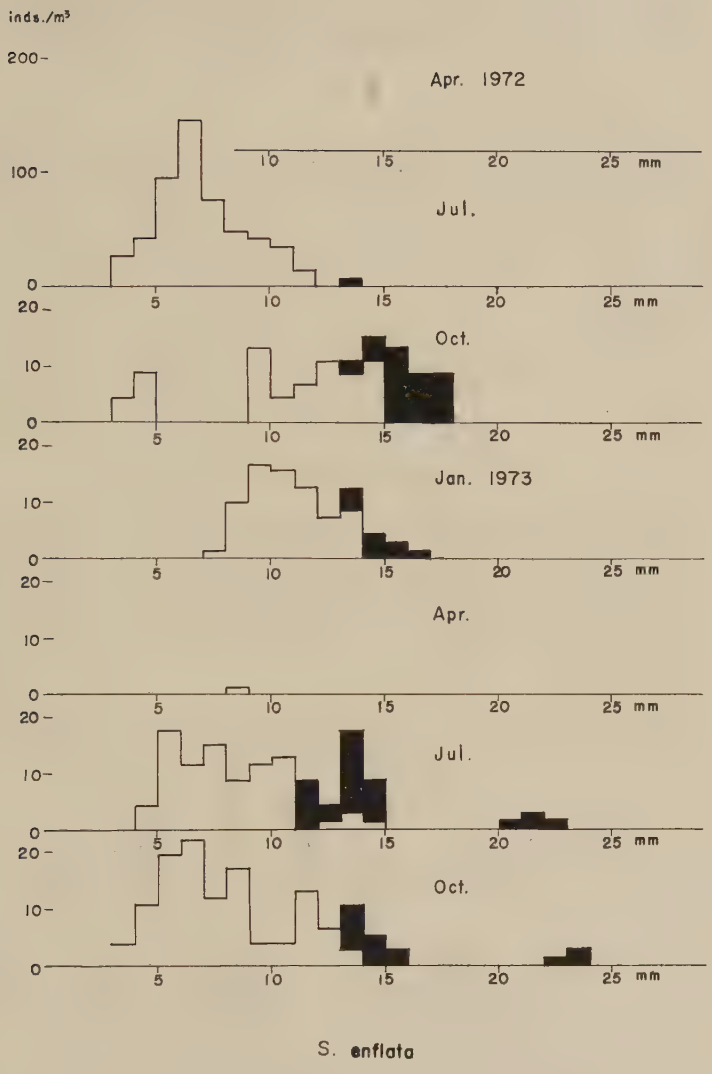

Fig. 7. Seasonal changes of the frequency distributions of the body length of *S. enflata* at the stations in the Section PN. Black columns show the mature forms.

less saline water appears in the surface layer. The stratification of water continues until late October. Hence, it can be said that *S. nagae* which increases in number in January and is entirely absent in October, is the "winter type" species. *S. enflata* which increases in number in July and decreases in number in April, is the "summer type" species in the area investigated.

Seasonal changes of the individual numbers of *S. nagae* and *S. enflata*, water temperature and salinity at 50m depth at the station PN-9 are shown in Fig. 8.

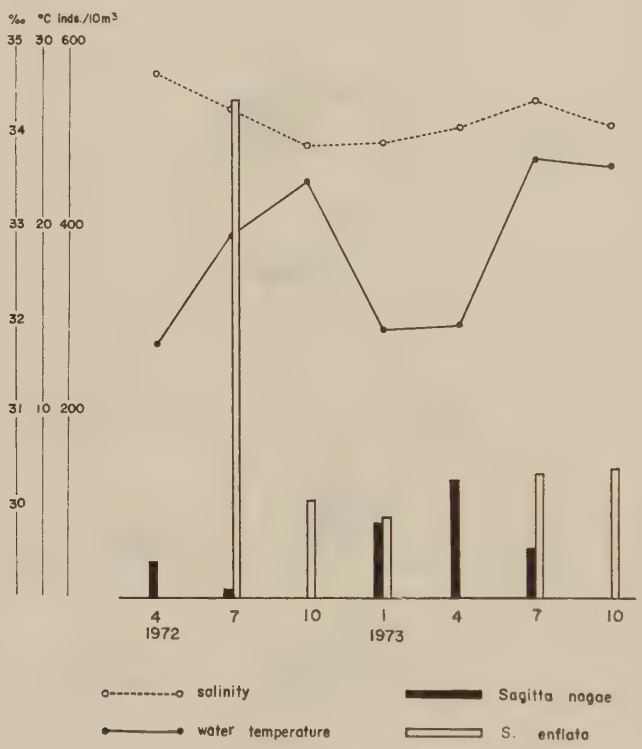

Fig. 8. Seasonal changes of the individual numbers of two species per ten cubic meters of water, water temperature (°C) and salinity (‰) at 50m depth at the station PN-9.

The populations of *S. nagae* are large in cold water and are small in warm water, while *S. enflata* increases in number in warm water and decreases in number in cold water. These facts also indicate that *S. nagae* is a winter type species and

S. enflata is a between type species. The relationship between the populations of the two species and salinity are obscure, so it seems that the behavior of the two species is more closely related to water temperature than to salinity.

Acknowledgements

The author expresses his hearty thanks to Dr. Yutaka KAWARADA of the Japan Meteorological Agency for his critical reading of this manuscript and kind suggestions. Great thanks are due to Mr. Fukutarō SHINJI, director of the Oceanographical Section of the Nagasaki Marine Observatory, and to the members of the section for their encouragements.

Thanks are also due to the officers and crew of the R/V Chōfū Maru for their effort to taking samples and data.

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東支那海における二・三のヤムシ類の分布の季節変化について

松　崎　正　夫
（長崎海洋気象台）

1972年4月から1973年10月までの3ケ月毎の定線観測の資料を用いて二，三の重要種の季節変化を調査した。

沿岸種の *Sagitta nagae* は冬から夏にかけて大陸棚奥部で増加し，混合水種の *S. enflata* は夏から冬にかけて混合水域で増加した。両種は塩分よりも水温の影響を強く受けているようであった。

黒潮水種の *S. hexaptera* と *S. lyra* ははっきりした季節変化を示さなかった。

The Oceanographical Magazine
Vol. 26, No. 2, pp. 73 to 89, March, 1975

On the normals of monthly sea surface temperatures from 1956 to 1970 for 5-degree squares in the western North Pacific Ocean

Hayato IIDA, Kiyoshi KATAGIRI, Ichiro MAEDA
and Etsuo KAMIHIRA

Japan Meteorological Agency

(Received on December 21, 1974)

Abstract: The 15-year normal of the monthly sea surface temperature for each 5-degree square are obtained from the data read off from the *Ten-day Marine Report* of Japan Meteorological Agency from 1956 to 1970. From the monthly normals for each 5-degree square, Fourier harmonic constants in time are obtained, which show that the seasonal change is nearly simple harmonic in the tropical sea area but skewness due to the 2nd harmonic becomes important in the subarctic region. The months in which the normals of sea surface temperature become maximum, are generally one month earlier than those of coastal sea surface temperature and about two months later than those of air temperature at the corresponding coastal stations, while the maxima of these values appear in the same month.

The gradients of monthly normals in the N-S direction have two maxima. One is between 25° and 31°N and the other between 36° and 41°N. They shift northwards in fall and southwards in early spring, although the former is not clear in summer.

1. Introduction

In 1971, we started to calculate new monthly normal of sea surface temperatures using data obtained during the period from 1956 to 1970 and planned to substitute these for the former one which covered the period from 1950 to 1959 with a less homogeneous data coverage. The new data were obtained from a series of ten-day sea surface temperature charts by reading off the temperature at the center of each one-degree latitude-longitude square, and summing these ten-day values to obtain monthly value for the square where two or more ten-day values are read off (IIDA et al. 1974, JMA 1975). By using these monthly data, the monthly sea surface temperature in each 5-degree square are calculated by,

$$T_n = \frac{\sum_i \sum_j A_{ij} T_{ij}}{\sum_i \sum_j A_{ij}} ,$$

where T_n, T_{ij} and A_{ij} are the temperature at the center of the 5-degree square n, the temperature and area factor at the 1-degree square of the i-th in latitude and j-th in longitude in the n-th 5-degree square, respectively. An area factor becomes zero when the temperature value is not obtained in the 1-degree square and is equal to the size of it when the temperature value is obtained. The numbers of the 5-degree squares are shown in Fig. 1. The 15-year normal of the monthly sea surface temperature for each 5-degree square is obtained as the arithmetic mean of the values for the month of each year during the period 1956 to 1970, only when ten or more values are available.

In addition to this, zonal mean temperatures are obtained from the normal temperature for each 1-degree square in order to know the north-south gradient of normal sea surface temperature. The zonal means are calculated for every 5 degrees in longitude.

The normal values of sea surface temperature have been calculated many times since the beginning of this century. The first one was obtained by Wada (1904). In 1911, the Kobe Imperial Marine Observatory began to collect sea surface temperature data of the entire North Pacific Ocean and calculated the sea surface temperatures for each 5-degree square. From the data, 5-year normals, 10-year normals, 15-year normals, etc. were calculated (SUDA et al. 1929, 1930 and 1931, and TSUKUDA et al. 1931). NAKAYAMA (1951 and 1958) and FUKUDA (1945) discussed the normals of sea surface temperature and long-term trend of them around Japan by using the collection of data.

During the World War II and in the immediate postwar period, oceanographic observations, including sea surface temperature observations, were seldom made. However, in the beginning of the fifties the organizations and institutions concerned with oceanographic observations and data collections began to regain capability for ocean environmental monitoring and survey—staff and facilities.

Japan Meteorological Agency also got the oceanographic tasks started, which included oceanographic observations by research vessels, collection of sea surface temperature data by ships of opportunity, fishing boats, etc., publication of oceanographic charts and so on. The sea surface temperature data were processed to produce sea surface temperature charts for each ten-day, which were published as the *Ten-day Marine Report* of Japan Meteorological Agency. The first issue was published in August 1946 and the number reached 500 in August 1960 and 1000 in

July 1974.

With the use of sea surface temperature data and charts, the forecasting of oceanographic conditions around Japan was started chiefly for long range weather forecasting in November 1950. The temperature data for 5-degree squares are more convenient for the purpose of studying long-range trend of oceanographic conditions, large scale air sea interaction, etc. than those for 1-degree one.

2. New normals of sea surface temperature for 5-degree square

The old normal of sea surface temperature for 1-degree squares was calculated in the same way from the sea surface temperature data obtained from *Ten-day Marine Report* as the new one (MASUZAWA et al. 1962). The difference in range and period of statistics between them is shown in the following table and figure 1.

	NEW NORMAL	OLD NORMAL
PERIOD	1956–1970	1950–1959
RANGE	10°–53°N	18°–41°N
	110°–180°E	117°–165°E

Figures 2-a and -b show the distributions for February and August, respec-

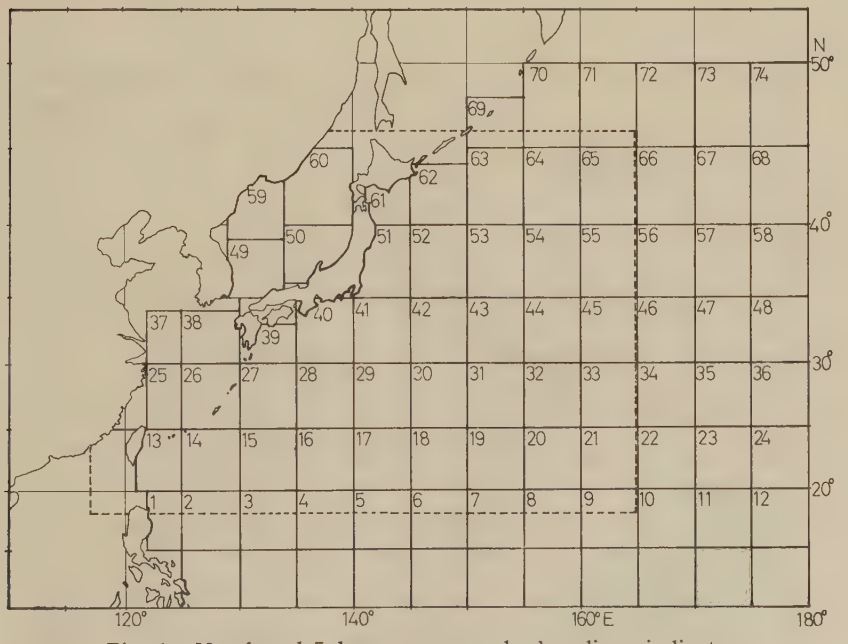


Fig. 1. Numbered 5-degree squares; broken lines indicate the areal extent of the old normals.

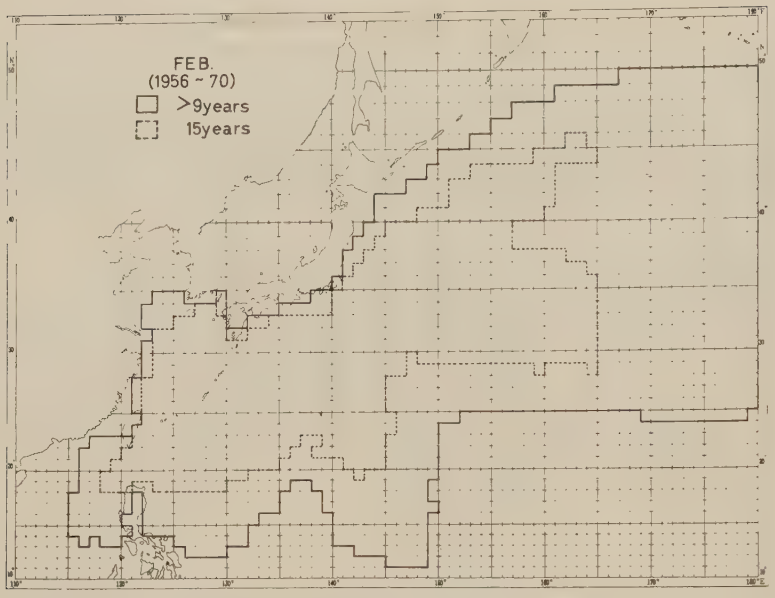


Fig. 2-a. Distribution of numbers of data available for February during the period 1956 to 1970.

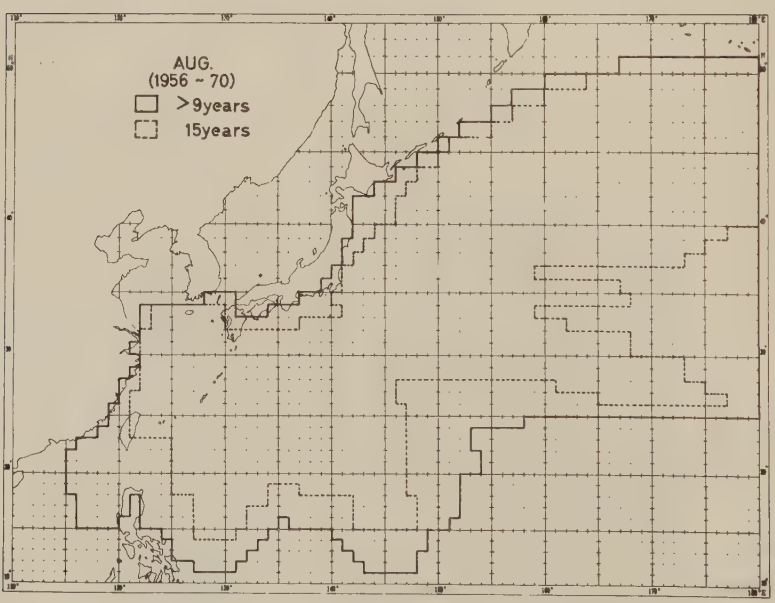


Fig. 2-b. The same as Fig. 2-a, for August.

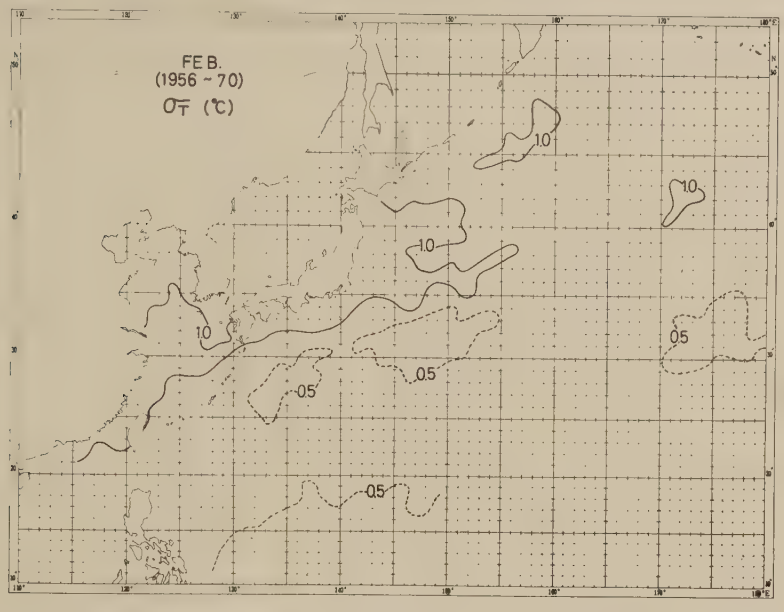


Fig. 3. Distribution of standard deviations for the new normals for February.

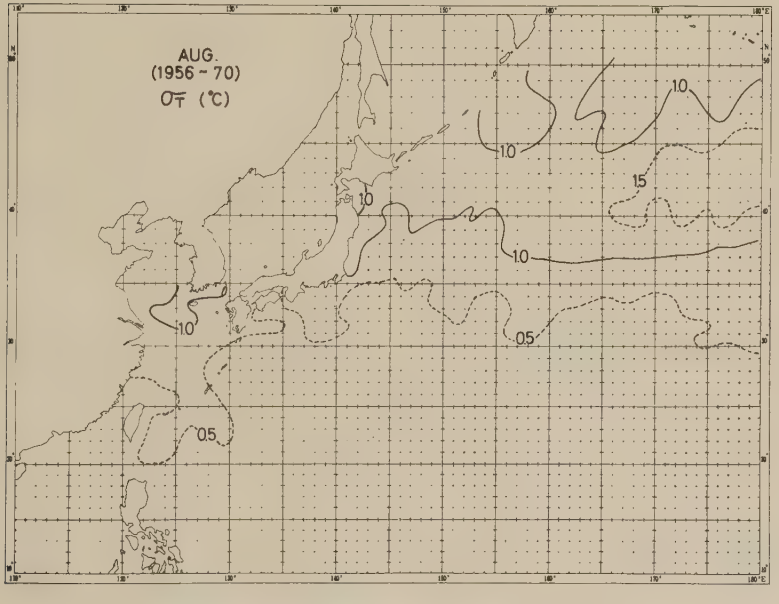


Fig. 4. The same as Fig. 3, for August.

Fig. 5. Deviations of the new normals from the old one for February.

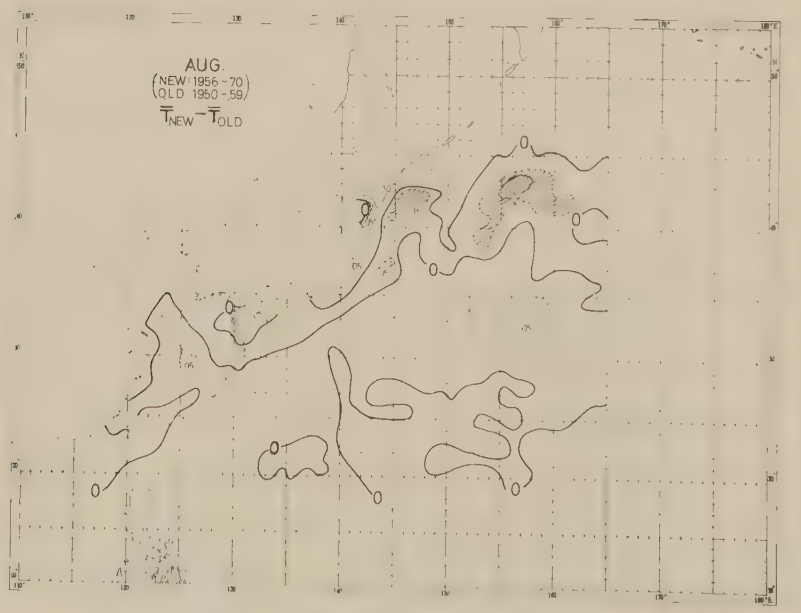


Fig. 6. The same as Fig. 5, for August.

tively, of the numbers of sea surface temperature values during the 15-year period 1956 to 1970. The numbers are larger in the warmer seasons than in the colder ones and larger along shipping routes from Japan to Shingapore, Java, Australia, Hawaii and North America via great circles.

The standard deviations of the new normal for February and August are shown in Figures 3 and 4, respectively. Standard deviations are larger in winter than in summer in the sea area south of 30°N and near Japan, while smaller in winter than in summer in the sea north of 30°N and east of 150°E. Of the areal differences, they are largest in the area between 35° and 45°N and smallest in the sea south of 35°N. Figures 5 and 6 show the distribution of the deviations of the new normal from the old one for February and August, respectively. They are generally very small except in the area very close to Japan.

The change in annual mean sea surface temperature in the east-west direction is different in latitude zones. In the two 5-degree zones north of 40°N, it becomes warmer to the east, in the two 5-degree zones between 25° and 35°N, it becomes colder, and in the zone between 35° and 40°N, the maximum appears in No. 53 square, the third one from the east coast of Japan (Table 1). The same things can be seen in the old normal.

The changes in monthly normals for mean sea surface temperature in the north-south direction is shown in Fig. 7. There are two places where the temperature gradient is larger. One is found between 25° and 31°N and the other is found between 36° and 41°N, which is the steepest and corresponds to the front between the Kuroshio Extension and the Oyashio. These places shift northwards in autumn and southwards in early spring. The former is not clear from July to October. The maximum temperature in the profile appears at the southernmost 1-degree belt in all the months except June, July and August. The temperature difference between 10° and 44°N becomes maximum, about 26°C, in May and April and minimum, about 16°C, in August and September.

Annual range of the new normal is shown in Table 2 with the 30-year normals of sea surface temperature at coastal stations in Japan. It is generally smaller to the east in all the latitudes. Along the north-south direction, it is largest between 35° and 45°N—the mixed zone of the Kuroshio and Oyashio waters, and becomes smaller both to the north and south, while it is largest at the northernmost coastal stations, Wakkanai in the Tsushima Warm Current region and Urakawa on the Pacific coast.

The month of maximum temperature ranges from July in the sea area south

Table 1. Normals of sea surface temperature.

T_0: annual mean sea surface temperature, ΔT_0: annual range, T_1: amplitude of annual term, O_1: month in which the annual term becomes maximum, T_2: amplitude of semi-annual term, and O_2: month in which semi-annual term becomes maximum.

Zone	Area No.	Harmonic constants					Observed			Standard deviation			
		T_0	T_1	O_1	T_2	O_2	Min. T	Max. T	ΔT	Jan.-Mar.	Apr.-Jun.	Jul.-Sep.	Oct.-Dec.
15~20°N	1	27.6	1.77	7.5	0.28	3.2	II 25.4	VII, VIII 29.2	3.8	0.6	0.5	0.5	0.4
	2	27.5	1.83	7.6	0.34	3.5	II 25.3	VII 29.2	3.9	0.6	0.5	0.4	0.4
	3	27.7	1.60	7.7	0.39	3.7	II 25.6	VII 29.2	3.6	0.6	0.5	0.4	0.5
	4	27.8	1.46	7.9	0.36	4.0	II 25.7	VII 29.3	3.6	0.5	0.4	0.4	0.4
	5	27.8	1.53	8.1	0.32	4.2	II 26.0	VII 29.3	3.3	0.4	0.4	0.4	0.4
	6	27.8	1.53	8.2	0.45	4.1	II 25.9	VII, VIII 29.2	3.3	0.5	0.4	0.4	0.4
20~25°N	13	26.1	2.84	7.6	0.16	2.5	I, II 23.1	VIII 29.1	6.0	0.7	0.5	0.5	0.5
	14	26.1	2.97	7.8	0.16	3.7	II 22.9	VIII 29.0	6.1	0.6	0.5	0.4	0.4
	15	26.1	2.87	7.9	0.32	3.7	II 23.0	VII 28.9	5.9	0.5	0.5	0.4	0.4
	16	26.3	2.73	8.0	0.41	3.7	II 23.2	VII 29.0	5.8	0.5	0.5	0.4	0.4
	17	26.6	2.56	8.1	0.38	4.3	II 23.6	VII, VIII 29.0	5.4	0.5	0.4	0.4	0.4
	18	26.6	2.57	8.2	0.43	4.4	II 23.7	VII, VIII 29.0	5.3	0.7	0.5	0.3	0.5
25~30°N	25	22.8					II 17.6	VIII 28.6	9.0	0.8	0.6	0.5	0.6
	26	24.3					II 20.3	VIII 28.9	8.6	0.8	0.6	0.5	0.5
	27	24.3	4.28	8.2	0.25	2.2	II 20.4	VIII 28.6	8.2	0.5	0.7	0.4	0.5
	28	24.4	4.26	8.3	0.09	2.0	II 20.3	VIII 28.5	8.2	0.5	0.6	0.4	0.5
	29	24.5	4.03	8.3	0.15	2.2	II, III 20.6	VIII 28.4	7.8	0.5	0.6	0.4	0.6
	30	24.5	4.04	8.4	0.23	5.9	II, III 20.5	VIII 28.4	7.9	0.5	0.6	0.4	0.5
	31	24.4	4.07	8.4	0.22	5.6	III 20.4	VIII, IX 28.2	7.8	0.7	0.8	0.4	0.5
	32	24.4	4.00	8.4	0.18	5.5	II, III 20.6	VIII, IX 28.2	7.6	0.7	0.8	0.4	0.6
	33	24.3	3.82	8.4	0.16	7.5	II 20.6	VIII, IX 28.0	7.4	0.7	0.7	0.3	0.6
	34	24.1	3.80	8.4	0.15	1.6	II 20.6	VIII, IX 27.8	7.2	0.6	0.6	0.4	0.4
	35	23.9	3.77	8.4	0.17	2.2	II 20.4	VIII, IX 27.6	7.2	0.5	0.7	0.3	0.5
	36	23.7	3.80	8.4	0.24	3.2	II 20.5	VIII, IX 27.4	6.9	0.6	0.7	0.4	0.5
30~35°N	37	17.8					III 9.7	VIII 26.8	17.1	0.9	0.7	0.8	0.8
	38	20.5					II, III 15.1	VIII 27.8	12.7	0.7	0.7	0.8	0.5
	39	23.0	4.51	8.2	0.43	3.4	II, III 18.9	VIII 28.2	9.3	0.8	0.7	0.5	0.4
	40	22.5	4.76	8.3	0.53	4.1	II, III 18.2	VIII 27.8	9.6	0.7	0.7	0.6	0.5

	41	22.3	4.84	8.5	0.67	3.5	III	18.0	VIII	27.8	9.8	0.5	0.6	0.5	0.5
	42	22.0	4.96	8.6	0.61	3.4	III	17.5	VIII	27.5	10.0	0.5	0.6	0.5	0.5
	43	21.8	4.94	8.6	0.60	3.2	III	17.3	VIII	27.3	10.0	0.5	0.6	0.5	0.6
	44	21.6	4.90	8.6	0.53	2.9	III	17.1	VIII	26.9	9.8	0.5	0.6	0.6	0.5
	45	21.4	4.88	8.6	0.67	3.2	III	17.1	VIII	26.8	9.7	0.4	0.6	0.5	0.5
	46	21.1	4.83	8.6	0.60	3.2	III	16.8	VIII	26.6	9.8	0.5	0.7	0.5	0.6
	47	20.9	4.72	8.6	0.69	3.7	III	16.7	VIII	26.4	9.7	0.4	0.7	0.6	0.7
	48	20.7	4.71	8.5	0.73	3.4	III	16.7	VIII	26.1	9.4	0.4	0.7	0.6	0.8
35～40°N	51	18.6	6.16	8.5	0.71	1.8	III	13.5	VIII	25.2	11.7	1.1	0.9	0.7	0.6
	52	17.8	5.82	8.4	0.64	3.4	III	12.6	VIII	24.7	12.1	0.8	0.7	0.6	0.5
	53	17.8	5.64	8.5	0.72	3.5	III	12.8	VIII	24.8	12.0	0.7	0.8	0.7	0.6
	54	17.4	5.32	8.7	0.75	3.6	III	12.6	VIII	23.8	11.2	0.5	0.7	0.9	0.7
	55	17.3	5.26	8.7	0.91	3.6	III	12.7	VIII	23.6	10.9	0.6	0.9	0.9	0.8
	56	17.2	5.19	8.7	0.95	3.4	III	12.9	VIII	23.4	10.5	0.5	0.8	1.0	0.7
	57	17.0	5.04	8.6	0.95	4.1	III	12.9	VIII	23.0	10.1	0.6	0.8	1.1	0.8
	58	16.8	4.70	8.6	1.03	3.6	III	12.9	VIII	23.1	10.2	0.6	0.9	1.1	1.1
40～45°N	62	9.9	7.02	8.6	1.15	4.0	II,III	4.2	VIII	17.9	13.7	0.8	1.1	1.1	0.7
	63	10.2	6.55	8.6	1.15	4.0	III	5.2	VIII	17.4	12.2	0.7	0.7	1.0	0.7
	64	10.9	5.64	8.7	1.00	4.1	III	6.2	VIII	17.6	11.4	0.6	0.8	1.0	0.7
	65	10.9	5.02	8.9	1.03	4.2	III	6.6	VIII	17.2	10.6	0.6	0.9	1.1	0.7
	66	10.9	4.84	8.7	1.01	4.4	III	7.0	VIII	16.9	9.9	0.6	0.8	1.1	0.8
	67	11.3	3.45	9.0	0.67	6.8	III	7.7	VIII	17.3	9.6	0.8	0.8	1.2	0.8
	68	11.7	3.17	8.9	0.72	3.7	III	8.4	VIII	17.6	9.2	0.7	0.8	1.4	1.0
45～50°N	70	6.0	4.78	8.7	1.31	4.0	III	2.1	IX	11.9	9.8	0.9	0.7	0.8	0.9
	71	6.5	4.76	8.7	1.30	4.1	III	2.8	IX	12.3	9.5	0.7	0.6	0.8	0.7
	72	6.6	4.38	8.7	1.12	4.2	III	3.1	IX	11.9	8.8	0.6	0.5	0.7	0.5
	73	6.8	4.03	8.7	1.08	4.0	III	3.5	VIII	11.9	8.4	0.6	0.5	0.8	0.5
	74	7.2	3.84	8.7	1.02	4.0	III	4.2	VIII	12.2	8.0	0.6	0.5	0.9	0.5

Air temperature in the open ocean

Victor	41°N	164°E	II	14.1	VIII 25.3	11.2	Annual Mean 19.2
Extra	39°N	153°E	II	5.4	VIII 23.3	17.9	Annual Mean 13.5
Marcus Is.	28.3°N	144.0°E	II	21.7	IX 28.3	6.6	Annual Mean 25.5

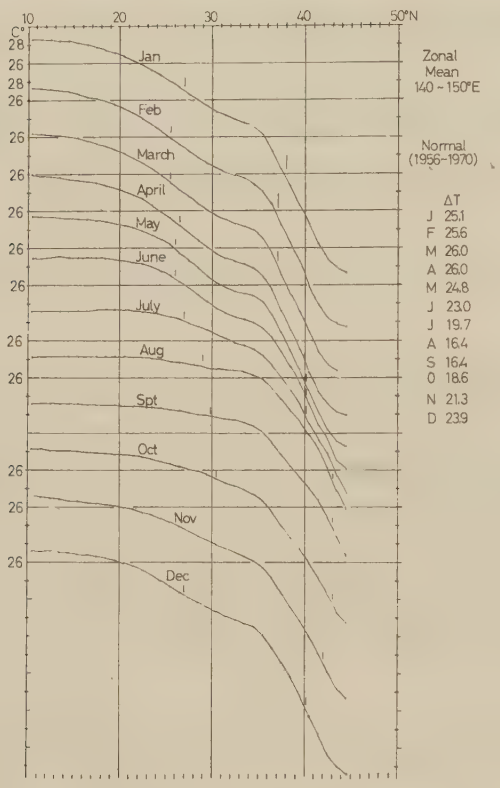


Fig. 7. N-S gradient of zonal mean value of the new normals between the meridians 140° and 150°E.
ΔT: Temperature difference between 10° and 44°N.

of 25°N to September north of 45°N, which is the same as those of coastal sea surface temperature and air temperature at the nearest costal station, and that of minimum ranges from February south of 30°N to March north of it, which is a month later than that of coastal temperature and two months later than that of coastal air temperature. These differences among the months when the offshore sea surface temperature and the coastal sea surface temperature become minimum, are supposed to be due to the difference between the vertical convective mixing processes in the shallow coastal area and in the open sea where it takes long time to lower the temperature of the entire surface layer.

Fourier coefficents of the new normal in tables 1 and 2 show the same things as mentioned above except for the 2nd or higher harmonics. The 2nd harmonics gives the seasonal change some skewness. Its amplitude decreases to the east in

Table 2. Normals of coastal sea surface temperature.
T_0 and T_A: annual mean sea surface temperature and air temperature at the coastal station, ΔT_0 and ΔT_A: annual range, T_1: amplitude of annual term, O_1: month in which annual term becomes maximum, T_2: amplitude of semi-annual term, and O_2: month in which semi-annual term becomes maximum.

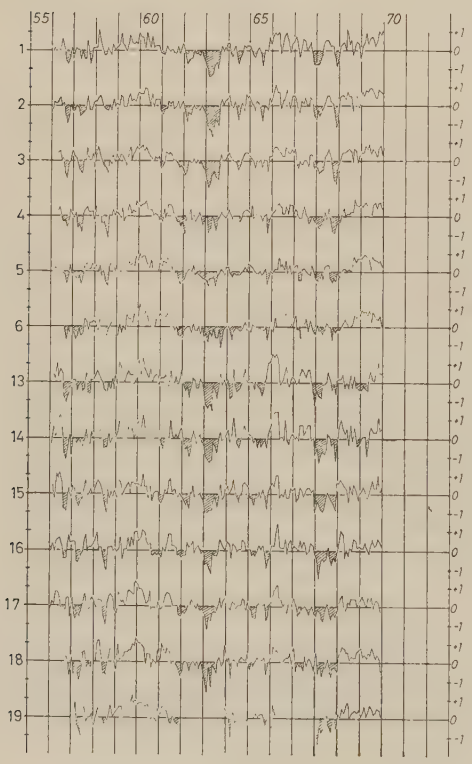
Coastal station			Harmonic constants					Observed			Observed 30-year normal of air temperature			
	Latitude	Longitude	T_0	T_1	O_1	T_2	O_2	Min. T_0	Max. T_0	ΔT_0	T_A	Min. T_A	Max. T_A	ΔT_A
Pacific Coast	N	E	°C	°C	month	°C	month	°C	°C			°C	°C	
Urakawa	42°09.5′	142°46.9′	8.90	9.06	8.3	1.08	4.4	II 0.5	VIII 19.1	18.6	7.6	I 3.3	VIII 20.0	23.3
Miyako	39°38.7′	141°58.1′	12.73	7.02	8.6	0.64	4.1	II 6.1	VIII 20.5	14.4	10.4	I −0.1	VIII 22.5	22.6
Onahama	36°56.7′	140°54.4′	15.19	6.72	8.3	0.62	4.5	II 8.9	VIII 22.8	13.9	12.8	I 3.0	VIII 24.1	21.1
Hachijo-jima	33°06.1′	139°47.3′	21.78	4.90	8.3	0.38	4.5	II 17.2	VIII 27.3	10.1	18.1	I, II 10.2	VIII 26.6	16.4
Omaezaki	34°36.1′	138°13.0′	18.08	7.36	7.9	0.38	4.8	II 10.9	VIII 26.2	15.3	15.9	I 6.0	VIII 26.4	20.4
Ashizuri-misaki	32°46.5′	132.57.5′	20.76	5.44	8.2	0.42	4.7	II 15.7	VIII 26.9	11.2	17.8	I 8.1	VII 27.3	19.2
Yaku-shima	30°27.0′	130°29.6′	22.84	5.14	8.0	0.32	4.0	II 17.9	VIII 28.4	10.5	19.2	I 11.2	VII 27.2	16.0
Naze	28°22.6′	129°29.9′	23.29	4.50	8.0	0.32	3.3	II 18.9	VII 28.0	9.1	21.2	I 14.2	VII 28.1	13.9
Naha	26°14.0′	127°41.0′	24.03	4.38	7.9	0.16	5.0	II 19.8	VII 28.4	8.6	22.3	I 16.0	VII 28.2	12.2
Miyako-jima	24°47.0′	125°17.0′	24.54	4.64	7.6	0.10	6.7	I 20.0	VI, VII 28.9	8.9	23.1	I 17.3	VII 28.1	10.8
Ishigaki-jima	24°20.0′	124°10.0′	24.77	4.54	7.5	0.20	7.1	I 20.2	VI, VII 29.0	8.8	23.7	I 17.8	VII 29.0	11.2
Yonakuni-jima	24°28.0′	123°01.0′	25.43	3.28	7.7	0.10	7.5	I 22.1	VII 28.6	6.5	23.4	I 17.5	VII 28.6	11.1
Japan Sea Coast														
Wakkanai	45°24.8′	141°41.0′	9.06	9.76	8.0	0.92	4.9	II −0.4	VII 19.9	20.3	6.3	I −5.8	VII 19.2	25.0
Suttu	42°47.4′	140.14.4′	12.09	8.36	8.1	1.16	3.6	II 4.7	VII 22.1	17.4	8.3	I −3.0	VII 21.2	24.2
Esashi	41°51.6′	140°07.6′	12.88	8.62	8.0	1.28	3.7	II 5.2	VII 23.5	18.3	9.4	I −1.7	VII 22.5	24.2
Tobishima			15.69	8.16	8.3	0.96	3.1	II, III 8.4	VII 25.4	17.0	11.8	I, II 0.9	VII 24.7	23.8
Aikawa	38°01.3′	138°14.6′	16.44	8.36	8.1	0.94	3.0	II 8.8	VII 26.5	17.7	13.0	II 2.6	VII 25.2	22.6
Wajima	37°23.4′	136°53.9′	16.56	8.68	8.0	0.68	2.5	II 8.3	VII 26.8	18.5	12.9	II 2.4	VII 25.0	22.6
Saigo	36°12.1′	133°20.2′	17.74	7.72	8.1	0.48	2.8	II 10.3	VII 26.9	16.6	13.8	I, II 3.7	VII 25.8	22.1
Hamada	34°53.9′	132.04.1′	18.30	7.54	8.1	0.58	3.1	II 11.1	VII 27.2	16.1	14.9	II 5.4	VII 26.2	20.8
Izuhara	34°12.2′	129°17.7′	18.95	6.08	8.4	0.82	3.8	II 13.5	VII 26.5	13.0	15.1	I 4.8	VII 26.3	21.5
Ushibuka	32°11.6′	130°01.6′	19.98	5.86	8.2	0.48	4.7	II 14.4	VII 26.3	11.9	17.3	I 7.6	VII 27.4	19.8

the sea area north of 40°N, increases to the east between 30° and 40°N and is rather irregular south of 30°N. Along the north-south direction, it is smallest, less than 1% of the amplitude of the lst harmonic, in the zone from 25° to 30°N, increases to both directions and becomes largest, more than 20%, in the northernmost zone.

3. Change in sea surface temperature

In figures 8~12, changes in sea surface temperature anomaly of the 5-degree squares are shown. They show a systematic pattern of change, that is, anomalies of the same sign continue for several years.

The pattern of changes is nearly the same in each of the three regions, the region south of the parallel 35°N, the so-called mixed zone of the Kuroshio and the Oyashio between the parallels 35° and 45°N and the Oyashio region north of 45°N, and shows significant phase lags among them. The amplitude of the change is smallest in the sea south of 35°N (especially small in the zone 25° to 35°N between 130° and 175°E), largest in the mixed zone and next to it in the Oyashio region.



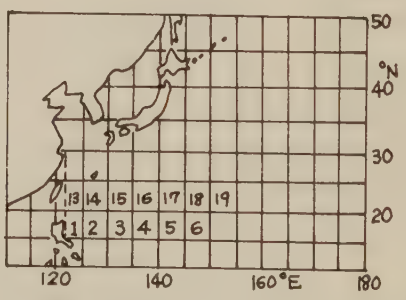
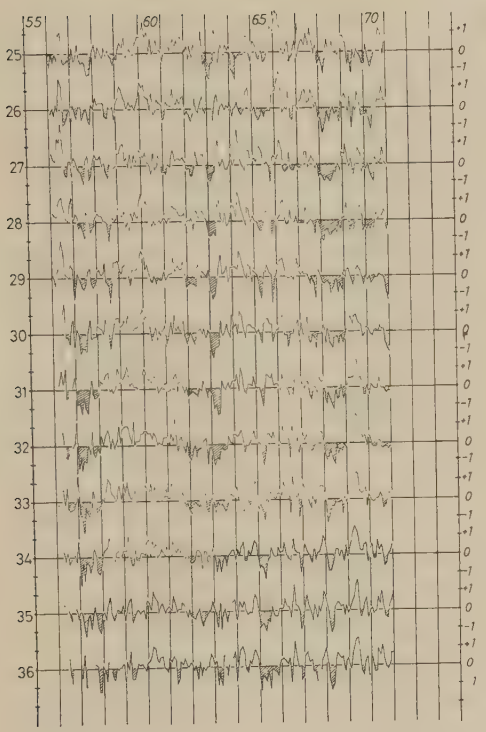


Fig. 8. Sea surface temperature anomalies for the 5-degree squares Nos. 1—6 and 13—19.



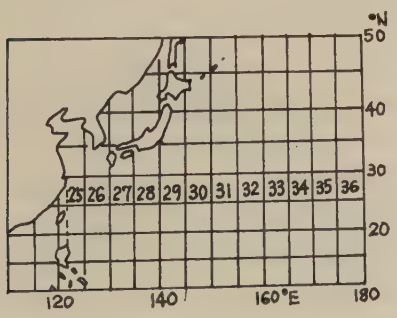
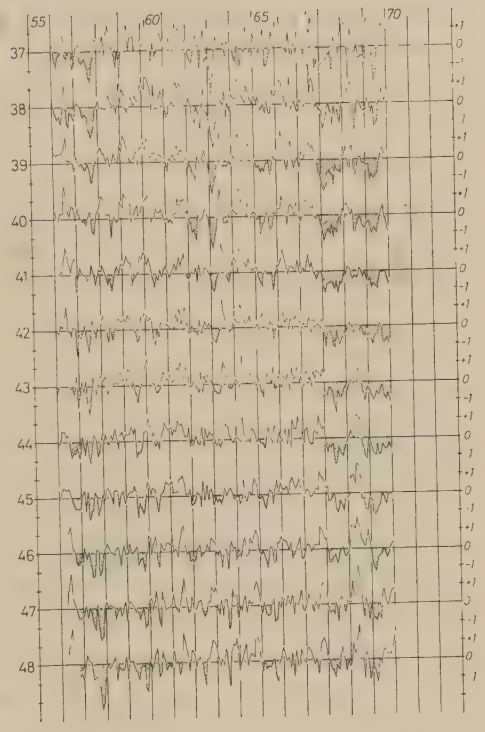


Fig. 9. The same as Fig. 8, for Nos. 25—36.



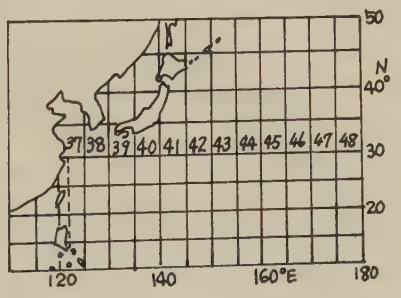


Fig. 10. The same as Fig. 8, for Nos. 37—48.

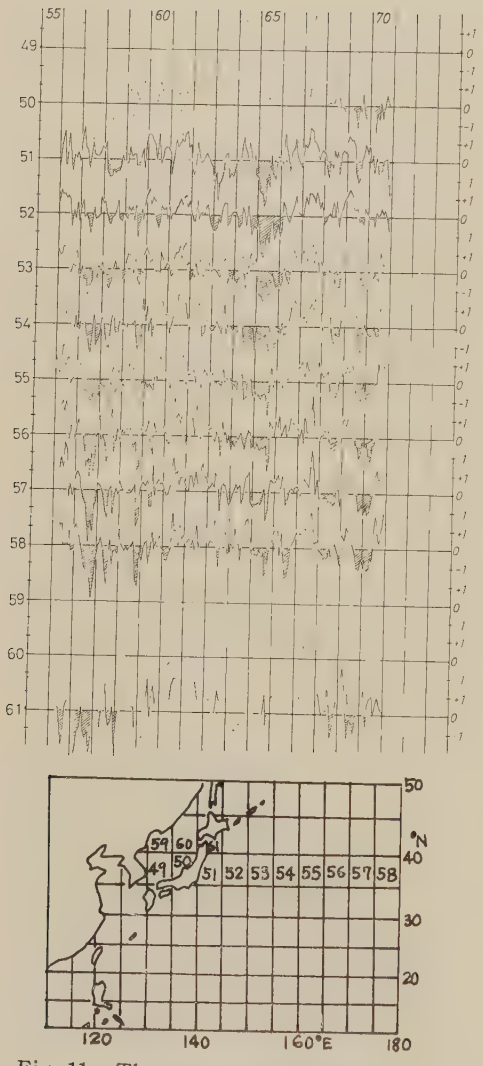
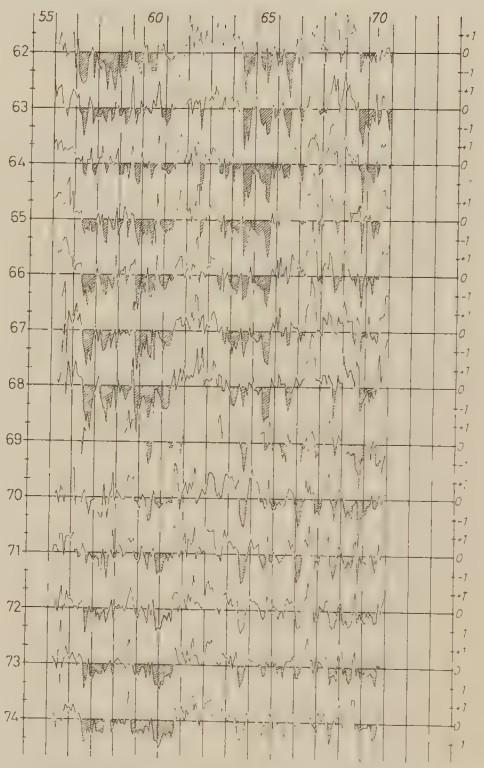


Fig. 11. The same as Fig. 8, for Nos. 49—61.



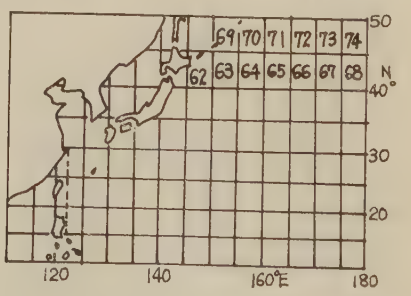


Fig. 12. The same as Fig. 8, for Nos. 62—74.

4. Concluding remarks

(i) The standard deviations of the new normal are larger in winter than in summer in the sea north of 30°N and near Japan, while smaller in winter than in the sea north of 30°N and east of 150°E.

They are largest in the area between 35° and 45°N—the mixed zone between the Kuroshio and Oyashio waters, smallest in the sea south of 35°N, and inbetween in the sea north of 45°N, the Oyashio region.

(ii) The annual mean sea surface temperatures become warmer to the east in the two 5-degree zones north of 40°N, while they become colder in the zones between 25° and 35°N. In the zone between 35° and 40°N, the maximum appears in the third 5-degree square from the Japanese ecoast.

(iii) There are generally two places where the north-south temperature gradient is larger. One appears between 36° and 41°N, which corresponds to the frontal zone between the Kuroshio and Oyashio. The other is found between 25° and 31°N. These places shifts northwards in autumn and southwards in early spring.

(iv) Annual range of the new normal is generally smaller to the east in all the latitudes. They are largest in the mixed zone along the north-south direction.

(v) The month of maximum sea surface temperature is the same as those of sea surface temperature and air temperature at the nearest coastal station, while that of minimum is a month later than that of coastal sea surface temperature and 2 months later than that of coastal air temperature.

(vi) Seasonal changes of sea surface temperature can be expressed almost completely by the 1st harmonic constant only in the zone from 25° to 30°N. The 2nd harmonic becomes more important to the north, the ratio of which to the 1st one reaches 20% in the northernmost zone.

(vii) The yearly changes of sea surface temperature show a systematic pattern of change. The pattern of positive or negative anomelies often continues for several years. The patterns of change are nearly the same in each of the three regions, the Oyashio, the mixed zone and the Kuroshio, and show significant phase differences among them.

Acknowledgement

The authors give their hearty thanks to Mr. T. YASUI of the oceanographical division for his kind advice.

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西部北太平洋における緯経度5度枡目の累年平均水温について

飯田隼人・片桐清之・前田一郎および上平悦朗

（気象庁海洋気象部）

気象庁では，海面水温の累年平均値として，1974年1月より，1956～70年の資料に基づく新累年平均値を古いもの（1950～59年）と替え，全国海況旬報中の水温偏差算出などのために使用している。新累年平均値は，1956～70年の全国海況旬報より各旬の緯・経度1度枡目の中心値を読み取り，それから得

られた各月の値をもとにして算出された。新累年平均値の特徴としては，(i) 平均値算出海域が旧来のものより広く，10～53°N, 110°E～180° の北太平洋をカバーしていること，および，(ii) 期間が15年間と5年長くなったことである。

新累年平均値に関しては次の事柄が容易に見出される。

(i) 標準偏差については，30°N 以南の海域および日本近海では，夏より冬が大きいが，30°N 以北の150°E 以東では夏より冬が小さい。地域的に見ると，混合水域で最大，黒潮域以南で最小，親潮域はこの中間である。

(ii) 年平均水温分布を見ると，混合水域の北半分より北では東に行くほど暖かくなるが，35°N以南では東ほど低温になっている。35°～40°N（混合水域南半分）では，本州東沖の第3番の枡目で最高となっている。

(iii) 南北方向の水温勾配には，一般に2ケ所ほど勾配の急な所がある。一つは36～41°N間の黒潮と親潮との混合水域にあたり，極めて大きな勾配を示している。もう一つは，25°～31°N の所にある小さい勾配のものである。これ等の位置は季節により変動し，秋に最北に，早春に最南に位置する。

(vi) 年較差は一般に東に行くほど小さくなっている。南北方向についていうと，混合水域で最大である。

(v) 最高水温は，同緯度の沿岸水温および沿岸水温と同月に現われるが，最低水温は，沿岸水温より1ケ月，沿岸気温より2ケ月ほどおくれて出現している。

(vi) 季節変化について見ると，30°N 以南の海域では，Fourier 級数の1次の項――年周項のみで，ほとんど完全に現わすことが出来るが，北に行くほど，2次の項――半年周項の割合が増え，親潮域では，半年周と年周項の比が 0.2 (20%) に達する。

(vii) 15年間の水温偏差の変動は，比較的系統的である。正あるいは負偏差は比較的長期間継続する（数年続くことが多い）。また，親潮域，混合水域，および黒潮域以南の海域のそれぞれの中では，偏差の変動は類似しているが，この三海域間には位相のずれが見られる。

気象庁

欧文海洋報告

第 26 巻

THE OCEANOGRAPHICAL MAGAZINE

Vol. 26

Published by the Japan Meteorological Agency

March, 1975

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昭和50年3月31日　発行

編集兼
発行者　気象庁
東京都千代田区大手町1の3の4

印刷者　藤原秀雄

印刷所　昌美印刷株式会社
東京都千代田区神田錦町3の16